



Montana Office of Public Instruction
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www.opi.mt.gov/IndianEd

Science Model Lesson

Grade 9

Created by Tom Stahley

When Raindrops Get Dry – Mountains, Rain Shadows and Life Approximate Duration: 200 minutes

Stage 1 Desired Results

Established Goals:

Montana Science Content Standard 1 Benchmark 4: Analyze observations and explain with scientific understanding to develop a plausible model.

Montana Science Content Standard 1 Benchmark 6: Explain how observations of nature form an essential base of knowledge among Montana American Indians.

Montana Science Content Standard 4 Benchmark 4: Collect and analyze local and regional weather data to make inferences and predictions about weather patterns; explain factors influencing global weather and climate; and describe the impact of fluctuations in weather and climate.

Essential Understanding 3: The ideologies of Native traditional beliefs and spirituality persist into modern day life as tribal cultures, traditions, and languages are still practiced by many American Indian people and are incorporated into how tribes govern and manage their affairs.

Additionally, each tribe has its own oral histories, which are as valid as written histories. These histories pre-date the “discovery” of North America.

Essential Understanding 4: Reservations are lands that have been reserved by the tribes for their own use through treaties, statutes, and executive orders and were not “given” to them. The principle that land should be acquired from the Indians only through their consent with treaties involved three assumptions:

- I. *Both parties to treaties were sovereign powers.*
- II. *Indian tribes had some form of transferable title to the land.*
- III. *Acquisition of Indian lands was solely a government matter not to be left to individual colonists.*

Essential Understanding 6: History is a story most often related through the subjective experience of the teller. With the inclusion of more and varied voices, histories are being rediscovered and revised. History told from an Indian perspective frequently conflicts with the stories mainstream historians tell.

Understandings: Students will understand that . . .

- climatic conditions in mountainous areas show great changes throughout the year.
- mountains cause a rain shadow effect that has

Essential Questions:

- In and around mountainous areas, what factors contribute to the patterns of vegetation growth, animal migration and weather?

<p><i>When Raindrops Get Dry (continued)</i></p> <ul style="list-style-type: none"> tremendous influence on the climate in nearby regions. wind patterns play an important role in the development of unique ecosystems near mountains. 	<ul style="list-style-type: none"> How are people influenced by these factors? What is the rain shadow effect, what causes it and where is it recognizable in Montana and other regions?
<p><i>Students will be able to...</i></p> <ul style="list-style-type: none"> analyze data in search of evidence for rain shadow sites. summarize the causes of weather and climate patterns that are associated with mountain and basin areas. site examples of how land, air and life are influenced by conditions around rain shadow areas 	<p><i>Students will know...</i></p> <ul style="list-style-type: none"> winds, mountains and moisture interact to create a rain shadow phenomenon in the area of the original Crow Indian reservation. climate data is regularly recorded and it can be analyzed for research. natural processes occur to create rain shadow areas with unique ecosystems.

Stage 2 Assessment Evidence

Performance Tasks: *The learner will . . .*

- extract, infer and summarize information from land use, climate, and other maps.
- compare and interpret climate data and recognize patterns related to elevation, precipitation, temperatures and vegetation.
- illustrate or model how mountains encourage orographic lifting and rain shadows that produce unique ecosystems.

Other Evidence:

- The learner will self-assess understanding during times of group and classroom dialogue.
- The teacher will assess student participation and the successful completion of guide sheet problems during the activities of the lesson.
- Students will successfully create an original product such as a detailed model, an illustration or a video to demonstrate their understanding.

Stage 3 Learning Plan

Learning Activities:

1. Hook Activity

- Retell historical accounts of the 1877 historical journey of Chief Joseph and tribal families as they fled from the pursuits of the military.
- Show the route of the Nez Perce/Nimiipuu (Nee-Me-Poo) National Historic Trail. Discuss the geographic obstacles and climatic conditions that confronted the tribe. Discuss needs of the people and the resources that were available.
- See the resources list provided for aid in researching the historical accounts.

2. Equip students with start-up ideas.

- Introduce the Essential Questions and explain the Desired Results from stage 2 of the lesson plan.

When Raindrops Get Dry (continued)

- b) Purposely avoid defining the “rain shadow” concept at this point to allow students to discover its meaning through exploration.
- c) Discuss with students the reasoning for the order of tasks in this lesson: “We will examine data from a study area *before* arriving at the main lesson concept (rain shadows) – so our work will lead us to discover pieces through inquiry that will help develop the meaning of the concept.”
- d) Let students know that they will explore visual and numerical data from an area commonly referred to as the Greater Yellowstone Area, but it very closely represents the original land area of the Crow (Apsáalooke) Reservation.
- e) Visually orient students with the land area of the original 1851 Crow Reservation.
- f) Share the following background information regarding Crow History, excerpted from *Montana Indians: Their History and Location*,

<http://www.opi.mt.gov/pdf/IndianEd/Resources/MTIndiansHistoryLocation.pdf>:

- i) The ancestors of the Crow Indians came from a “land of many lakes” probably in the headwaters of the Mississippi or further north in the Winnipeg Lake region. They eventually settled along the Missouri River in what are now the states of North and South Dakota. The people lived in semi-permanent villages of lodges covered with earth. They became known as the “people who lived in earthen lodges.”

Nearly 400 years ago, the people divided into two factions. One group, the Hidatsa, remained along the Missouri. The other group, the Apsaalooke, migrated westward and eventually claimed most of what is now eastern Montana and northern Wyoming as homeland. At the time of the breakup, this group, numbering about 500, was made up of several families. Its population reached about 8,000 before the smallpox epidemic of the middle 1800s. At that time, the Apsaalooke or Crow Tribe traveled in two or three groups or bands.

In 1825, the Crow Tribe and the United States signed a treaty of friendship. In 1851, the Fort Laramie Treaty established the boundaries for several tribes, including an area of 38,531,147 acres designated for the Crow Indians. This was followed by the Fort Laramie Treaty of 1868, which reduced the Crow holdings to 8,000,409.20 acres.

An Act of Congress in 1882 resulted in a further reduction of the land. For compensation, the government committed to buy livestock and build houses for them. By this time, the tribe had been settled within the boundaries of the reservation for about ten years. In 1890, more land was ceded to the government for which they received \$946,000. In 1905, the last large land cession was made leaving about three million acres of land for the tribe.

The Crow Indians have always felt the government failed to give them adequate compensation for the land it acquired. The estimated value was far more than the five cents per acre they received. In 1904, the Crow Tribe first initiated legal proceedings for just compensation for lands taken. In 1962, the Court of Indian Claims finally awarded a \$10,242,984.70 judgment to the Crow Indians.

Since 1905, further attempts have been made to reduce the Crow Reservation. Sen. Dixon in 1910, Sen. Meyers in 1915, and Sen. Walsh in 1919, all sponsored legislation in Congress to open the balance of the Crow Reservation for settlement by the public. All attempts failed. An Act of Congress passed on June 4, 1920, sponsored by the tribe itself, divided the remainder of the reservation into tracts which were allotted to every enrolled member of the tribe. The titles to these lands are held in trust by the federal government and allottees may not dispose of their lands without the consent and approval of the government. The rough mountain areas were withheld from such allotment and remain in communal tribal ownership.

- ii) Present both versions of the Crow Migration Narrative, found at <http://lib.lbhc.edu/index.php?q=node/13> and <http://lib.lbhc.edu/index.php?q=node/133>.
- iii) View the original Crow land holdings by showing the reservation map at <http://lib.lbhc.edu/index.php?q=node/159>

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Other Possible Options:

- iv) Present the Location Map of the Greater Yellowstone Area handout for viewing and discussion since that area approximates the size of the original reservation.
- v) On a map showing Montana and Wyoming cities, students can shade in the approximate area of the original 1851 Crow Reservation's area after connecting the following cities with a dot-to-dot style boundary line:
 - Montana locations – Gardiner, Livingston, Harlowton, Roundup, Terry, Broadus
 - Wyoming locations – Buffalo, Kaycee, Lander, Yellowstone Lake
- vi) Use the plot options of Google Earth to outline the approximate original boundary using the above Montana and Wyoming locations listed above.
- g) Discuss the changes in Crow homelands.
- h) Identify mountainous areas within these Crow homelands.

3. Inquiry preparation

- a) Review the rules, routines and expectations of the inquiry process and clarify the roles of both the teacher and the students. (This lesson uses the “variation over space” inquiry mode – see resources list).
- b) Consider choices for having students complete the tasks. Some classes might respond well in groups of 3 to 4 while others work best in pairs. Group work is recommended so students can share their previous knowledge and expand on various discussion points.
- c) Review the mountainous areas that were identified within Crow homelands. Be prepared to discuss the changes within these homelands over time once again. Consider which of these areas students should concentrate on within the inquiry portion of the lesson.
- d) Identify the lesson's exploration problem, “How do mountains influence the local climate?”

4. Review and supply materials

- a) Provide group members with a set of colored maps of the Greater Yellowstone area in the order listed below, and review them briefly. Teachers may decide to display the maps using a PowerPoint slide set. Some students might benefit by having the teacher handout the maps separately rather than as a set to help groups limit their focus before moving to another map.

Four maps make up the set, <http://pubs.usgs.gov/wri/wri984269/index.html>:

- Location Map of the Greater Yellowstone Area*, found in the upper left-hand corner of the following image: <http://pubs.usgs.gov/wri/wri984269/fig1.gif>.
- Land Cover and Land Use Map of the Greater Yellowstone Area*, <http://pubs.usgs.gov/wri/wri984269/fig18.gif>.
- Average Annual Precipitation Map of the Greater Yellowstone Area (with visual topography)*, <http://pubs.usgs.gov/wri/wri984269/fig4p1.gif>.
- Enlarged Portion Map within the Greater Yellowstone Area (with cities), which can be found as an attachment to this lesson plan.

*These maps can be expanded and then saved as images for printing from links on the web page.

5. Inquiry Opportunities

- a) Provide Guide Sheet 1-Examining Maps of the Greater Yellowstone, review strategies for its use and monitor student progress as they complete the guide sheet.
- b) Provide time for discussion (groups or entire class) of what was gleaned from the maps by the students.

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- c) Distribute the Climate-related Data from the Greater Yellowstone Area handout. Students complete Guide Sheet 2-Examining the Climatic Data of Selected Locations as a way to guide them to interpret the data.
- d) To provide opportunities for higher-level thinking, students use multiple maps and other information to complete Guide Sheet 3-Generalizing Climatic Patterns. Students will record data onto their maps and make generalizations from the information.
- e) Allow time for students to compare the generalizations they recorded on the table of Guide Sheet 3 with those of the answer key. Answers may vary slightly with different interpretations.
- f) Guide Sheet 4-The Science Behind the Climatic Patterns engages students in understanding natural science processes. After recognizing patterns established with the map tasks, students learn the topics of adiabatic temperature changes, orographic lifting and the rain shadow effect. Students are asked to record informational notes on this guide sheet, so teachers may choose to illustrate and discuss the content within a class lecture. With advanced groups, students can more independently explore and retrieve information from various weather-related science resources. Teachers can use information by Steve W. Woodruff on atmospheric stability located on a web page at <http://data.piercecollege.edu/weather/stability.asp> for background content and animated visuals.

6. Application Opportunities

- a) Guide Sheet 5-Mountain Influences on Land and People directs students to apply their learning to the Greater Yellowstone Area study site.
- b) Plan time for class discussion of student responses to the guide sheet problems so varied influences of the area's rain shadow effect become clear.
- c) Tie the lesson to the opening historical account of the Nez Perce Trail. Students should have come to realize that if the prevailing wind direction is known, then it is often possible to predict where rainfall and vegetation would be plentiful as well as where the land may be dry with sparse plant growth. Some Native people developed ways of survival by using keen observations. One might assume that there was an understanding of the rain shadow concept, as well as other contemporary scientific concepts, by some Native people long before contemporary scientists formalized the idea and its explanation.
- d) Continue this exploration by examining the homelands of the Crow people and how these factors influence their life ways both historically and contemporarily.

7. Assessment Opportunities

- a) Upon completion of the lesson, teachers can use various assessment strategies which may include:
 - detailed, original illustrations of the rain shadow concept and its implications on an area.
 - models made with clay or Play-Doh and completed with information pinned to the model to show the geographic and land cover features, the orographic lifting area, the rain shadow location, etc.
 - a written test or quiz on the based on the Understanding and Essential Questions of the lesson.

Materials/Resources Needed:

- Map images needed as handouts for completing the lesson guide sheets are included in the lesson materials.
- Nez Perce Historical Trail information: <http://www.fs.usda.gov/main/npnht/maps-pubs> and <http://www.fs.usda.gov/main/npnht/about-trail>

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- Crow Reservation Map: <http://lib.lbhc.edu/index.php?q=node/159>
- Greater Yellowstone Area:
 - detailed article: <http://pubs.usgs.gov/wri/wri984269/index.html>
 - location map and information: <http://pubs.usgs.gov/wri/wri984269/intro.html>
 - land use and land area map and information:
<http://pubs.usgs.gov/wri/wri984269/anthropo.html#lulc>
 - precipitation map and information:
<http://pubs.usgs.gov/wri/wri984269/envsett.html#clim>
- Inquiry Science: Kastens, Kim A. and Ann Rivet. "Multiple Modes of Inquiry in Earth Science." *The Science Teacher* 75 (2008): 26-31. available at <http://learningcenter.nsta.org/search.aspx?action=quicksearch&text=Multiple%20Modes%20of%20Inquiry%20in%20Earth%20Science>
- Atmospheric stability and rain shadow effect:
 - article by Steve W. Woodruff <http://data.piercecollege.edu/weather/stability.asp>
 - Montana-oriented page by Rod Benson <http://formontana.net/precip.html>

Directions: *In this activity you will be given a set of maps of the Greater Yellowstone Ecosystem. The maps provide valuable information. Study them carefully, allowing for think-time, so you can extract the details that will allow you to make inferences later in the activity.*

As a group member, contribute to the discussion and completion of this guide sheet. Teams get deeper meaning from a map by following the sequence of steps below.

- *All members verify they have located the correct study map.*
- *Spend quiet time personally studying the map.*
- *Verbally, share and discuss understandings you gathered from the map.*
- *Lastly, select several understandings to record on the guide sheet.*

1. Map 1: Location map – **What were several understandings gleaned from this map? Write them below.**

2. Map 2: Land Cover and Land Use map - **Write several understandings gleaned from this map.**

3. Map 3: Average Annual Precipitation map (with visual topography) - **Write several understandings gleaned from this map.**

4. Map 4: Enlarged Portion map (with cities) - **Write several understandings gleaned from this map.**

5. Combine what you now understand from the four maps into a summary paragraph similar to what might appear in a travel magazine or newspaper that tells others about the Greater Yellowstone Area. (If necessary, finish your writing on the back.)

Climate-related Data from
the Greater Yellowstone Area

Class Period _____
Name(s)

The climatic conditions within the Greater Yellowstone Area vary considerably by location. Below is a data table with several of the area's cities and an assortment of data values. These will be helpful when comparing the environmental differences of the study area.

Review the data columns before going on to Guide Sheet 2.

Location	Average Max Temperature for JAN. (°F)	Average Max Temperature for JULY (°F)	Elevation (feet above sea level)	Average Annual Precipitation (to nearest .1 inch)	Average Annual Snowfall (to nearest .1 inch)
Cooke City, MT	24.1	74.0	7572	25.7	207.2
Red Lodge, MT	32.8	78.3	5561	21.2	122.5
Burgess Junction, WY	27.5	70.0	8087	21.0	243.3
Yellowstone Lake, WY	22.7	71.5	7736	19.9	161.0
Billings, MT	36.4	89.1	3215	13.3	25.4
Hardin, MT	33.5	90.7	2900	11.9	21.2
Cody, WY	36.0	84.8	5082	9.9	39.5
Clark, WY	36.2	86.1	4226	7.4	23.6
Greybull, WY	30.1	90.4	3793	6.9	20.1
Belfry, MT	34.3	87.9	3855	6.8	13.6
Powell, WY	31.1	86.5	4386	6.2	16.3

Climatic data from Western Regional Climate Center

Source page is <http://www.wrcc.dri.edu/Climsum.html>

Elevation data from U. S. Geological Survey

Source page is <http://geonames.usgs.gov/pls/gnispublic/>

Directions:

- A. Obtain and preview the Climate-related Data from the Greater Yellowstone Area. Note the way the data is organized in the table.*
- B. The first few problems given below serve as guided questions that model for students various ways to dig out information from a set of data. Answer the given problems.*
- C. You are then expected to write and answer your own set of problems from the data table and write them at various levels of difficulty.*

1. Basic-Level Problems – Answers come directly from the table.

1.1. Name a city with an average maximum temperature for July that exceeds 90 °F.

1.2. List the cities that have the highest elevation and the lowest elevation. Include their elevation values.

1.3. List the cities with the highest and lowest average total precipitation. Include their precipitation values.

***Create additional Basic-Level Problems as you review the data table. Provide answers to all problems.**

1.4.

1.5. *

1.6. *

Guide Sheet 2 (continued)

2. Higher-level Problems – **Answers require comparing, translating, summarizing, inferring, etc.**

2.1. Compare temperature data for Billings and Cooke City.

2.2. As you compare the elevations of Hardin and Red Lodge, what can be said about them?

2.3. Select a city with over 200 total inches of snowfall for the year. Name the city, give the snowfall value and convert the value to feet. (Show the mathematical problem.)

***Create additional Higher-Level Problems as you review the data table. Provide answers to all problems.**

2.4. *

2.5. *

2.6.

Directions:

1. *Locate the Enlarged Portion map of the Greater Yellowstone Area. To help discover relationships between locations, place data from the data table onto the enlarged map. The graphic shown at the bottom of the map shows you how to properly place the data around each city shown on the map.*
2. *After placing the data onto the enlarged map, you are ready to make inferences about why the climates vary in the Greater Yellowstone Area and what may be causing the differences. Answer the following problems.*
3. Research and then explain the difference between *mountains* and *mountain ranges*.
4. What mountainous areas exist in this area of Montana and Wyoming?
5. Use various maps to identify and draw an accurate outline of the Crow Reservation onto the Enlarge Portion map of the Greater Yellowstone Area. Locate and label the community of Crow Agency, which is the location of the Crow Tribal Headquarters.
6. What mountainous areas exist within the Crow Reservation boundaries?
7. Low, broad areas between mountainous areas are sometimes known as basins. Locate and identify the basin shown on the map.
8. Look for patterns that appear on your map. Making generalizations as you complete the table below will help you see climate patterns more clearly. Complete the table below to show the generalizations.

CITY AND GEOGRAPHIC LOCATION (on mountain, mountain flank, basin, plain)	RELATIVE ELEVATION (above 6000 ft, 4000-6000 ft, below 4000 ft)	RELATIVE PRECIPITATION LEVELS (high moisture, low moisture, very low moisture)	RELATIVE TEMPERATURES (cold, cool, mild, hot)		RELATIVE SNOWFALL DEPTH (extreme snow, moderate snow, modest snow, little snow)
			During Winter	During Summer	
Belfry, in basin		very low moisture		hot	
Billings, _____					modest snow
Burgess Junction, _____	above 6000 ft				
Cody, _____					
Cooke City, in mountains			cold		

Greybull, _____					
Powell, _____					
Red Lodge, _____					
Now, use the generalizations for the towns above to infer generalizations for Crow Agency, MT.					
Crow Agency _____					

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Name(s)

Directions: Complete the problems below as instructed by your teacher.

1. One pattern that shows up in the Greater Yellowstone Area is that ___ (circle one: basin areas, mountain areas) seem to be hot in the summer. This occurs mainly due to the area's ___ (circle one: vegetation, elevation, rivers).

2. Another pattern that shows up is that locations in the basin area receive ___ (circle one: abundant, moderate, little) precipitation while areas nearby in the mountains receive ___ (circle one: abundant, moderate, small) amounts.

Predict what you believe might be the causing this precipitation pattern before we study the actual cause. _____

3. One additional pattern that is not shown on the map is that of the wind direction. The study region of the map lies within a worldwide wind belt called the Prevailing Westerlies. Therefore, on most days, the wind will generally blow across this region from the west to the east. Of course as storms pass, winds will fluctuate from this pattern. Draw arrows on your map to show the typical wind pattern across this part of Montana and Wyoming.

4. Research/Notes & Labeled Visuals

Directions: From research sources or from information presented by your teacher, add notes and labeled visuals to show your understanding of the science topics.

4.1. Topic: adiabatic temperature changes: cooling – Illustrate an understanding of the relationships between rising air, expansion, cooling, dew point temperature, condensation, cloud formation and precipitation.

4.2. Topic: adiabatic temperature changes: warming – Illustrate an understanding of the relationship between sinking air, compression, warming, dew point temperature, evaporation and water vapor.

Guide Sheet 4 (continued)

4.3. Topic: orographic lifting – Show an understanding of a mountain barrier, rising air, cooling, cloud formation and precipitation.

4.4. Transfer your thinking to the topography of the Greater Yellowstone Area. Give the scientific explanation for the tremendous snow accumulation depths at Cooke City and Burgess Junction.

4.5. Account for the dry climate of the Bighorn Basin. Word your explanation in scientific terms. Does Crow Agency fall within the Bighorn Basin?

4.6. Topic: rain shadow – Define the term and tell how it applies to the study area map.

4.7. Imagine the elevation changes you would experience if you walked the Montana-Wyoming boundary as marked on the map.

4.7.1. On the back of this handout or on separate paper, draw a large, general profile (side view) of the area along the Montana-Wyoming border. Exaggerate it so the mountains and basins are clearly noticeable.

4.7.2. Show and label the mountain and basin areas by name.

4.7.3. Add visuals to the profile to show and label orographic lifting, and typical locations of cloud formation and rain shadow areas.

4.8. Explore other areas with geographic settings similar to that of the Greater Yellowstone Area. Predict several places where you would likely find rain shadow conditions.

Directions: Complete the following problems. Previous activity work and map handouts may be helpful.

Class Period _____
Name(s) _____

- 1. What type of land cover is typically found in the Absaroka and Bighorn Mountains?**

- 2. Of what value is that type of land cover?**

- 3. What is the typical land use within the Bighorn Basin?**

- 4. What would be the value of that type of land?**

- 5. Describe the changing vegetation types along a route from Cooke City to Red Lodge and then to Belfry.**

- 6. What factor is mostly responsible for that change in vegetation?**

- 7. Today, many elk in the Greater Yellowstone Area spend summers in high elevation areas and then migrate to lower elevations in winter. Relate the elk migration to the climatic conditions found there.**

- 8. Years ago, many elk and buffalo often stayed at lower elevations throughout the year. What changed in our world that caused them to seek higher elevations?**

- 9. How would drought conditions possibly affect the migration of animals?**

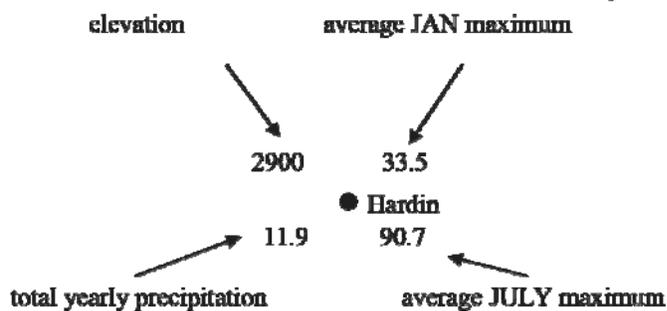
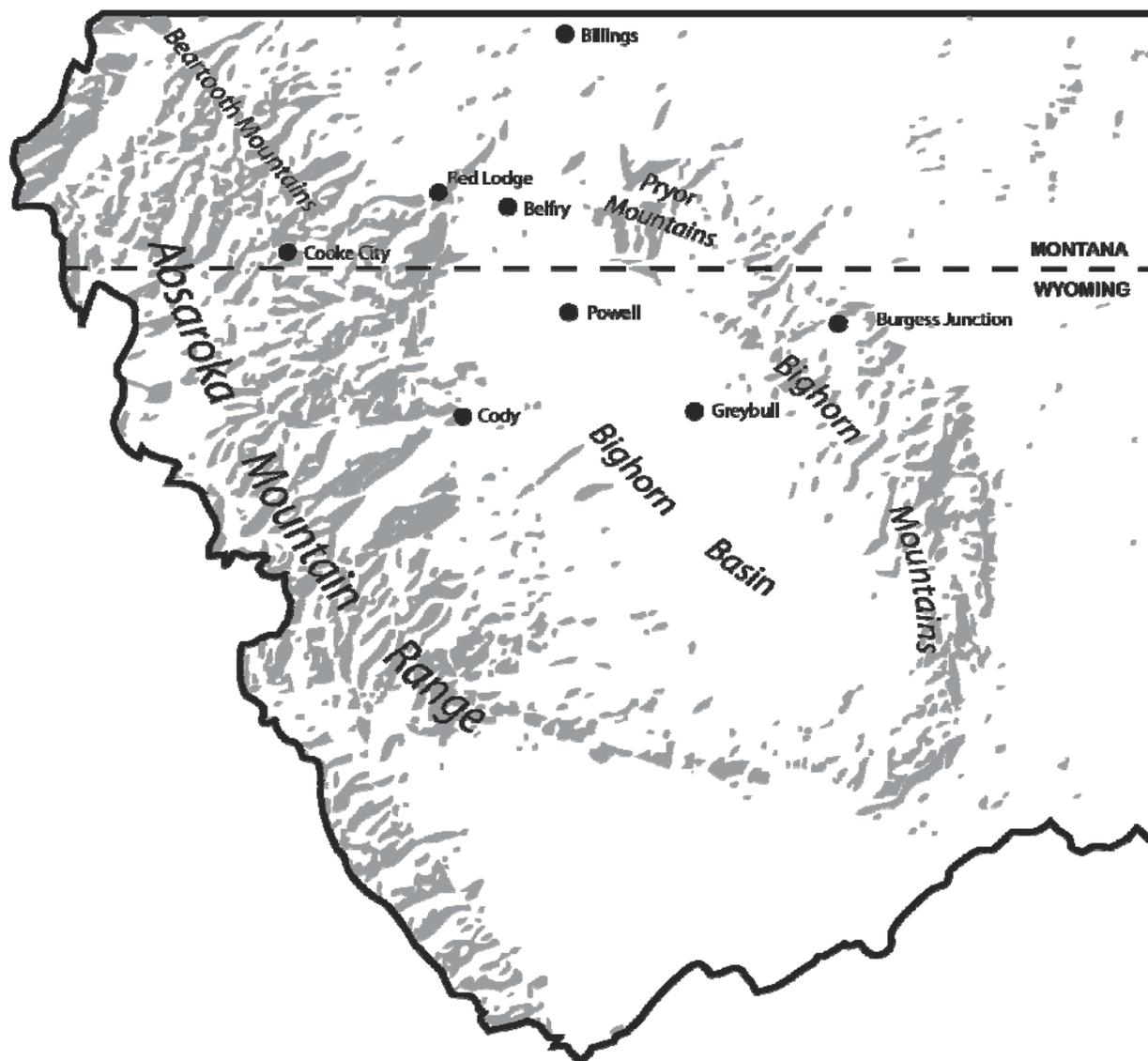
10. During certain situations, some Native tribes found it necessary to move from one area to another. List situations you can think of that might cause them to move? Are any related to climatic conditions?

11. Consider the activities of people who currently live in the Greater Yellowstone Area. In what ways are their activities influenced by the rain shadow effect that occurs in the area? Brainstorm and list several of those activities.

12. As we began our lesson you considered whether travelers such as Chief Joseph could predict what the land ahead of the trail might have been like. Comment on that idea again.

13. Think about the climatic patterns related to the geography of the Greater Yellowstone Area and how these factors influence the life ways of Crow people, historically and contemporarily, related to food and shelter.

Directions: Place climate-related data provided by your teacher onto the map as modeled in the lower illustration.



Map by Tom Stahley, lesson author

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Answers will vary.

4. Map 4: Enlarged Portion map (with cities) - **Write several understandings gleaned from this map.**

Answers will vary.

5. **Combine what you now understand from the four maps into a summary paragraph similar to what might appear in a travel magazine or newspaper that tells others about the Greater Yellowstone Area. (If necessary, finish your writing on the back.)** **The Greater Yellowstone Area covers a large part of southeastern Montana and northern Wyoming where many rivers drain into the Yellowstone River. Most of the area is range, forest, and agricultural land with about 65% of it being range land. Several mountains spread their way across parts of the Greater Yellowstone region. These mountain areas receive a great deal of moisture. Many areas outside the mountainous regions are quit dry. The most populated city in the area is Billings, Montana with other cities and small towns scattered from higher mountain areas to the lower areas along rivers. With its spectacular mountains and beautiful flowing rivers, it is an inviting area enjoyed by many.**

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Clark, WY	36.2	86.1	4226	7.4	23.6
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1. Basic-Level Problems – Answers come directly from the table.

1.1. Name a city with an average maximum temperature for July that exceeds 90 °F.

Hardin or Greybull

1.2. List the cities that have the highest elevation and the lowest elevation. Include their elevation values.

highest elevation: Burgess Junction, 8087 feet

lowest elevation: Hardin, 2900 feet

1.3. List the cities with the highest and lowest average total precipitation. Include their precipitation values.

highest total precipitation: Cooke City, 25.7 inches

lowest total precipitation: Powell, 6.2 inches

***Create additional Basic-Level Problems as you review the data table. Provide answers to all problems.**

1.4. * Answers will vary.

1.5. *

1.6. *

Guide Sheet 2 (continued)

2. Higher-level Problems – Answers require comparing, translating, summarizing, inferring, etc.

2.1. Compare temperature data for Billings and Cooke City.

Temperatures in Cooke City average about 12°F cooler in January and about 15°F in July.

2.2. As you compare the elevations of Hardin and Red Lodge, what can be said about them?

The elevation at Red Lodge is nearly double that at Hardin.

2.3. Select a city with over 200 total inches of snowfall for the year. Name the city, give the snowfall

value and convert the value to feet. (Show the mathematical problem.)

possible answers: Cooke City with 207.2 inches; $207.2 \text{ inches} \div 12 = 17.3 \text{ feet of snow}$

Burgess Junction with 243.3 inches; $243.3 \text{ inches} \div 12 = 20.3 \text{ feet of snow}$

*Create additional Higher-Level Problems as you review the data table. Provide answers to all problems.

2.4. * **Answers will vary.**

2.5. *

2.6. *

Directions:

1. **Locate the Enlarged Portion map of the Greater Yellowstone Area.**
To help discover relationships between locations, place data from the data table onto the enlarged map. The graphic shown at the bottom of the map shows you how to properly place the data around each city shown on the map.
2. *After placing the data onto the enlarged map, you are ready to make inferences about why the climates vary in the Greater Yellowstone Area and what may be causing the differences. Answer the following problems.*
3. **Do research and then tell the difference between mountains and mountain ranges.**
A mountain range refers to an area of interconnected mountains, so a mountain is a smaller, high area.
4. **What mountainous areas exist in this area of Montana and Wyoming?**
Absaroka Range, Beartooth Mountains, Big Horn Mountains and the Pryor Mountains
5. **Use various maps to identify and draw an accurate outline of the Crow Reservation onto the Enlarge Portion map of the Greater Yellowstone Area. Locate and label the community of Crow Agency, which is the location of the Crow Tribal Headquarters.**
To be determined by teacher.
6. **What mountainous areas exist within the Crow Reservation boundaries?**
The Big Horn Mountains, the Pryor Mountains, and the Wolf Teeth Mountains
7. **Low, broad areas between mountainous areas are sometimes known as basins. Locate and identify the basin shown on the map. The Bighorn Basin is located between the Absaroka and Bighorn mountains.**
8. **Look for patterns that appear on your map. Making generalizations as you complete the table below will help you see climate patterns more clearly. Complete the table below to show the generalizations.**

CITY AND GEOGRAPHIC LOCATION (on mountain, mountain flank, basin, plain)	RELATIVE ELEVATION (above 6000 ft, 4000-6000 ft, below 4000 ft)	RELATIVE PRECIPITATION LEVELS (high moisture, low moisture, very low moisture)	RELATIVE TEMPERATURES (cold, cool, mild, hot)		RELATIVE SNOWFALL DEPTH (extreme snow, moderate snow, modest snow, little snow)
			During Winter	During Summer	
Belfry, in basin	below 4000 ft	very low moisture	cool to mild	hot	little snow
Billings, on plain	below 4000 ft	low to very low moisture	mild	hot	modest snow
Burgess Junction, in mountains	above 6000 ft	high moisture	cold	cool	extreme snow
Cody, on mountain flank	4000-6000 ft	very low moisture	mild	hot	modest snow
Cooke City, in mountains	below 4000 ft	very high moisture	cold	cool	extreme snow

Greybull, in basin	below 4000 ft	very low moisture	cool	hot	little snow
Powell, in basin	4000-6000 ft	very low moisture	cool	hot	little snow
Red Lodge, on mountain flank	4000-6000 ft	very high moisture	cold to cool	mild	moderate to extreme snow
Now, use the generalizations for the towns above to infer generalizations for Crow Agency, MT.					
Crow Agency To be determined by teacher.	To be determined by teacher.	To be determined by teacher.	To be determined by teacher.	To be determined by teacher.	To be determined by teacher.

Class Period _____
Name(s)

Guide Sheet 4-The Science Behind the Climatic Patterns

Directions: Complete the problems below as instructed by your teacher.

1. One pattern that shows up in the Greater Yellowstone Area is that ___ (circle one: basin areas, mountain areas) seem to be hot in the summer. This occurs mainly due to the area's ___ (circle one: vegetation, elevation, rivers).

2. Another pattern that shows up is that locations in the basin area receive ___ (circle one: abundant, moderate, little) precipitation while areas nearby in the mountains receive ___ (circle one: abundant, moderate, small) amounts.

Predict what you believe might be the causing this precipitation pattern before we study the actual cause.

Answers will vary

3. One additional pattern that is not shown on the map is that of the wind direction. The study region of the map lies within a worldwide wind belt called the Prevailing Westerlies. Therefore, on most days, the wind will generally blow across this region from the west to the east. Of course as storms pass, winds will fluctuate from this pattern. Draw arrows on your map to show the typical wind pattern across this part of Montana and Wyoming.

4. Research/Notes & Labeled Visuals

Directions: From research sources or from information presented by your teacher, add notes and labeled visuals to show your understanding of the science topics.

4.1. Topic: adiabatic temperature changes: cooling – Illustrate an understanding of the relationships between rising air, expansion, cooling, dew point temperature, condensation, cloud formation and precipitation.

Answers will vary.

4.2. Topic: adiabatic temperature changes: warming – Illustrate an understanding of the relationship between sinking air, compression, warming, dew point temperature, evaporation and water vapor.

Answers will vary.

Guide Sheet 4 (continued)

4.3. Topic: orographic lifting – Show an understanding of a mountain barrier, rising air, cooling, cloud formation and precipitation.

Answers will vary.

4.4. Transfer your thinking to the topography of the Greater Yellowstone Area. Give the scientific explanation for the tremendous snow accumulation depths at Cooke City and Burgess Junction.

Cooke City and Burgess Junction are both located where air is often lifted to the cool, high elevations of the mountains. This adiabatic cooling process caused by orographic lifting results in frequent cloudy skies and precipitation. In winter the precipitation accumulates as deep snow.

4.5. Account for the dry climate of the Bighorn Basin. Word your explanation in scientific terms. Does Crow Agency fall within the Bighorn Basin?

The Big Horn Basin is located at a low elevation where air warms as it drops off the mountains that are located west of the basin. Warm air produces water vapor instead of clouds so the little precipitation falls in the basin.

4.6. Topic: rain shadow – Define the term and tell how it applies to the study area map.

A rain shadow is an area that receives little precipitation due to a barrier, such as a mountain. In the study area, the Absaroka Mountain Range is a barrier that causes a lot of moisture to fall in the mountains leaving very little moisture to fall in the basin located downwind from the mountains.

4.7. Imagine the elevation changes you would experience if you walked the Montana-Wyoming boundary as marked on the map.

4.7.1. On the back of this handout or on separate paper, draw a large, general profile (side view) of the area along the Montana-Wyoming border. Exaggerate it so the mountains and basins are clearly noticeable. **Answers will vary...**

4.7.2. Show and label the mountain and basin areas by name. **Answers will vary...**

4.7.3. Add visuals to the profile to show and label orographic lifting, and typical locations of cloud formation and rain shadow areas. **Answers will vary...**

4.8. Explore other areas with geographic settings similar to that of the Greater Yellowstone Area. Predict several places where you would likely find rain shadow conditions.

Where the wind blows eastward across high mountains and then the elevations drop to a basin or plain there would likely be a rain shadow. Browning, Montana is in the rain shadow of Glacier Park, much of eastern Montana is under rain shadow conditions due to the influence of the Rocky Mountains and Washington's Cascade Mountains make Seattle wet and Spokane dry.

Directions: Complete the following problems. Previous activity work and map handouts may be helpful.

Name(s) _____

1. What type of land cover is typically found in the Absaroka and Bighorn Mountains? **forest land**

2. Of what value is that type of land cover? **timber for harvesting, protection for wildlife, recreation**

3. What is the typical land use within the Bighorn Basin? **range land (with some agricultural land)**

4. What would be the value of that type of land? **livestock grazing, farm and ranch use, recreation**

5. Describe the changing vegetation types along a route from Cooke City to Red Lodge and then to Belfry. **Timbered-forested land at Cook City changes to range land of grasses and shrubs at lower elevations. Eventually you will find agricultural land near Belfry.**

6. What factor is mostly responsible for that change in vegetation? **Elevation (which influences the climate)**

7. Today, many elk in the Greater Yellowstone Area spend summers in high elevation areas and then migrate to lower elevations in winter. Relate the elk migration to the climatic conditions found there.

During winter, deep snow covers the food supply of the elk in many areas so they move to lower elevations in winter. In the spring and summer, they return to the mountains where the moisture and cooler weather produce thicker grass cover for food.

8. Years ago, many elk and buffalo often stayed at lower elevations throughout the year. What changed in our world that caused them to seek higher elevations?

Basin and valley areas saw a substantial increase in human population. Many larger animals moved to the mountainous areas that provided them protection from the threatening activities of people.

9. How would drought conditions possibly affect the migration of animals?

When drought conditions persist, less grass is available. As food supplies dwindle, animals will migrate to where food is more plentiful.

10. During certain situations, Indians found it necessary to move from one area to another. List situations you can think of that might cause them to move? Are any related to climatic conditions?

Survival during earlier times was dependent on having food available in the area you lived in. If the food supply was unavailable due to drought (a climatic condition) or possibly fire, the people would need to move to other areas. The threat of war from outside groups also influenced their movements.

11. Consider the activities of people who currently live in the Greater Yellowstone Area. In what ways are their activities influenced by the rain shadow effect that occurs in the area? Brainstorm and list several of those activities.

People today are able to live somewhat comfortably in areas like the Big Horn Basin. With modern technology many grow irrigated crops, raise livestock, buy food in stores and many live in air-conditioned homes. Some move cattle to mountain areas during summer. People do visit the mountain areas for vacation, to ski and snowmobile, and to hunt big game. Thunderstorms still roll into the rain shadow area which can affect plans for the day or wipe out a farmer's income with the passing of crop-destroying hail.

12. As we began our lesson you considered whether travelers such as Chief Joseph could predict what the land ahead of the trail might have been like. Comment on that idea again.

Because of their great observational skills, it is likely that Indian people of long ago were aware of how the mountains, moisture and prevailing winds combined to produce rain shadow areas. As they moved eastward through mountains and into basins they knew where the "raindrops would get dry".

13. Think about the climatic patterns related to the geography of the Greater Yellowstone Area and how these factors influence the life ways of Crow people, historically and contemporarily, related to food and shelter. **Answers to be determined by teacher and students.**